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THE EFFECT OF METAL FILLER ON STRUCTURE FORMATION OF COMPOSITE MATERIALS

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The idea of producing ceramic composites with a high content of metal filler by semidry molding with subsequent drying and firing is proposed. The choice of a ceramic matrix and a metal filler is substantiated.

The main research trends in the field of metal ceramics are oriented researching new, particularly high-density fine-crystalline high-strength materials with specific properties. The reason for this is the fact that cermet materials have unique physicochemical and chemical properties that are not found in any other class of materials.

Cermet composites are extensively used in different sectors, such as electronics, aircraft, machine building, metal treatment, metallurgy, car industry, rocket industry, laser engineering, etc.

We have proposed the idea of producing ceramic composite materials with a high content of metal filler by semidry molding with subsequent drying and firing. Ceramics normally has low tensile strength combined with a high Young modulus and a low impact viscosity. Cracking becomes one of the reasons for the destruction of such ceramics under high temperatures. The introduction of a metallic filler leads to a very interesting combination of essential service parameters: high strength (including high temperatures), fatigue strength, etc. Thus, the metal filler complements the nonmetal matrix and the resulting composite exceeds the initial components by its physicochemical parameters.

A metal filler has a number of advantages compared to traditional binders used in construction materials, such as polymer, cement, etc. These advantages are related to a high level of strength parameters, plasticity, viscosity, and good casting and technological properties. In choosing a metal filler we gave preference to aluminum, since this metal is relatively inexpensive and has a low melting temperature (660°C).

The matrix was based on kaolinite and montmorillonite clays which under firing generate physicochemical reactions between the components, which makes it possible to obtain materials with preset service characteristics.

Since aluminum melt is poorly compatible with clay particles, 0.1–1.0% surfactant was introduced into clay to improve its wettability. Chemical modification of clay with Al^{3+} ions from aqueous solutions and thermomechanical modification of the aluminum matrix combined with its dispersing made it possible to increase the content of aluminum in the composite to 20% and yet to avoid spalling or structure loosening by unstable alumina interlayers.

Materials based on a ceramic matrix and an aluminum filler were prepared by mixing modified components, their subsequent molding, drying, and firing.

Sintering kinetics was studied by the method of consecutive firings in the temperature range of 900–1300°C with an interval of 50°C. Mutual dissolution of the solid phase in the liquid phase is corroborated by the fact that a dense material was obtained based on a mixture containing up to 20% aluminum.

Special attention in firing was paid to identifying an optimum regime for temperature rise, exposure, and cooling. It should be noted that temperature rise in the interval of 100–600°C should be gradual, as it is related to the removal of physically fixed water and burning out of organic impurities from initial materials. Inner stresses arise in this process, which may cause the formation of micro- and microcracks in the sample.

Complex physicochemical transformations occur in firing modified ceramic mixtures containing an aluminum filler. As a consequence of thermal destruction of minerals and partial oxidation of aluminum, free oxides are formed. This leads to the formation of an intermediate finely dispersed phase, i.e., a solid solution.

The modification transformation of β -quartz into α -quartz occurs at a temperature of 580–590°C, which increases the sample volume and heat consumption (in cooling this process has a reverse direction). This should be taken into account in choosing an optimum firing regime.

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In the temperature interval above 600°C, part of aluminum gets oxidized and produces aluminum oxide that participates in the formation of the composite structure (by mutual dissolution and subsequent chemical reactions). Physical adhesion caused by the interaction of electrons at the atomic level is formed between aluminum that has not been oxidized and the modified filler surface.

Within the temperature interval of 800–1200°C the sintering process proceeds with participation of the liquid phase reacting with the solid phase. Melted aluminum in mixtures increases the quantity of melt and decreases its viscosity. To lower the firing temperature, group two metal oxides (calcium, magnesium, zinc oxides) are introduced into the composite as additives and decrease (by 50–80°C) the melt formation temperature and the temperature of the first exothermic effect [1, 2]. The introduction of alkali-earth metal oxides into clay increases the rate of mullite crystallization.

We investigated the sintering and structure formation of ceramic mixtures in which calcium oxide was introduced. Enriching the melt with Ca^{2+} ions accelerates the volumetric diffusion and crystallization processes. The formation of

aluminosilicates occurs more intensely already at the temperature of 900°C.

The physiochemical processes and structural modifications occurring in ceramic mixtures in the presence of a metal filler during their preparation, modifying, and heat treatment influence the structure and properties of materials.

The production of such materials is based on crystallization processes (increased number and size of crystals) and solid-and-liquid-phase sintering. The selection of appropriate conditions for heating, thermal treatment, and firing has made it possible to control the modification of structure and properties of ceramic composites within wide ranges.

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